A SIXTEENTH-CENTURY DRAWING OF AN ASTROLABE MADE BY KHAFĪF GHULĀM 'ALĪ B. 'ĪSĀ (c. 850 A.D.)

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RIASSUNTO

Questo articolo identifica un disegno, eseguito da Antonio da Sangallo il Giovane, di un astrolabio costruito dal famoso astrolabista di Baghdad Khafīf (850 d.C. ca.). Al Museum of the History of Science di Oxford è conservato l'unico astrolabio di Khafīf oggi esistente, del quale si pubblica una fotografia. Grazie alla notevole precisione della copia di Antonio e alla somiglianza di questa copia con la rete di un astrolabio anonimo, pure conservato a Oxford, sembra possibile confermare che la parte non firmata debba essere stata costruita dallo stesso Khafīf. Il presente articolo conclude che l'astrolabio del disegno deve essere stato un lavoro tardo di Khafīf, dato che è più completo di quello di Oxford, con aggiunte apportate in Andalusia prima che Antonio lo vedesse.

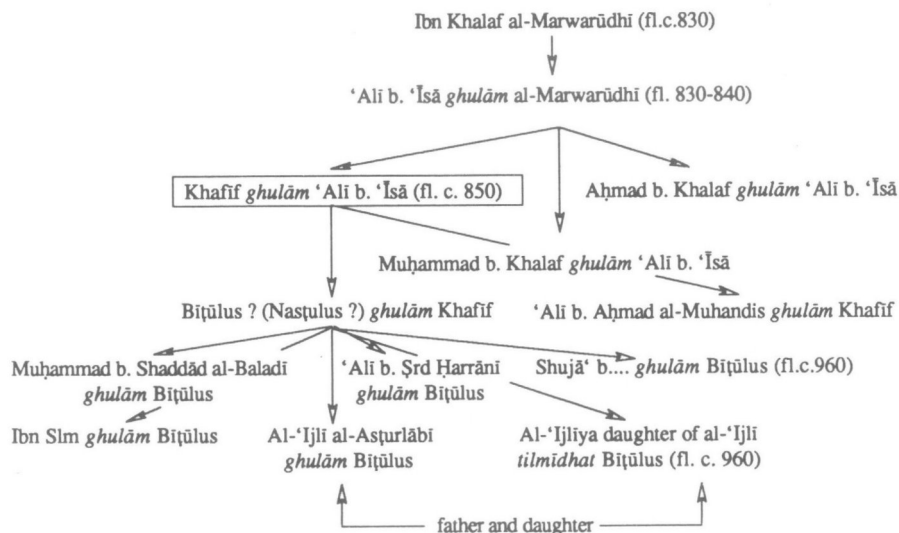
Introduction

While working on the drawings of Antonio da Sangallo the Younger (the Florentine architect who built the greater part of St. Peter's in Rome), my colleague and good friend, the historian of Renaissance art and technology Gustina Scaglia, brought to my attention a copy of the two halves of a once-folded sheet in the Uffizi, Gabinetto dei Disegni e Stampe, now catalogued as U1454 A, *recto* (Figure 1) and *verso* (Figure 2), executed ca. 1520 A.D.[1] On

[1] The drawings are to be published in the *Corpus of the Drawings of Antonio da Sangallo the Younger*, vol. I, ed. Nicolas Adams (Architectural History Foundation, New York, 1991?).

that sheet Antonio the Younger draughted in great detail three main parts of an Arabic astrolabe, namely, the mater, the back of the same (Figure 1) and the rete (Figure 2). The drawing also included the picture of what looks like obvious replacements of an alidade, a screw-pin and a rivet-horse (upper central part of Figure 1).

From the photo she had at hand, I could at the time, decipher only parts of the name of the original astrolabe maker whose astrolabe was being drawn, and could only give my general impression of the kind of astrolabe the artist must have had in front of him. But for various reasons, I remained to be puzzled by that sudden appearance of a drawing of an Arabic astrolabe among the notes of a famous Renaissance engineer. I was willing to leave the matter at that had it not been for this nagging curiosity, and the perseverance of my friend to 'get to the bottom of it'. The next step was to acquire better photographs of the original paper, and she supplied them with reasonable haste. It was only then that I could read very clearly the name of the astrolabe maker, obviously first engraved on the rim of the upper right-hand quadrant of the back, and slavishly copied on the same spot in the drawing. Looking at it carefully, there was no doubt in my mind that I was looking at a drawing of an astrolabe now apparently lost but originally signed (*ṣana'ahu/ṣan'at*) by the ninth century famous Baghdādī astrolabist Khafīf *ghulām* (student/apprentice? of) 'Alī b. 'Īsā. This astrolabist was famous enough to have been mentioned in the medieval Arabic literary and scientific sources.[2] In addition, he must have occupied a distinguished position among the instrument makers of his time, since he was first mentioned quite prominently among the astrolabists of the ninth and the tenth century by the intellectual historian and bibliophile of the tenth century, al-Nadīm (wrote in 986). The following chart, extracted from al-Nadīm's work, highlights the position of Khafīf, and clarifies his relationship to the other generations of instrument makers:

[2] See, for example, *Kitāb al-Fihrist li-l-Nadīm*, by Abū al-Faraj Muḥammad b. Abī Ya'qūb Isḥāq al-Ma'rūf bi-l-warrāq [986 A.D.], ed. R. Tajaddud, Tehran, 1971, pp. 342-343, and Ibn Yūnus, «Le livre de la grande table Hakémite (*al-Zīj al-Ḥākimī*)», *Notices et extraits des manuscrits de la Bibliothèque Nationale*, VII, 1804, pp. 16-240, esp. pp. 55.

From this chart we note that Khafīf was not only responsible for the instruction of two students, but through one of them he was responsible for the instruction of six others. This brings the number of instrument-makers to eight who were in some way connected to him. Adding him to the group, the number becomes quite significant for then it will account for more than half of the sixteen instrument-makers of the ninth and tenth centuries who were mentioned by al-Nadīm[3]. In this regard, one must assume that these sixteen names were indeed those of the best instrument makers of those two centuries to deserve a special section in al-Nadīm's work, which is mainly literary. In fact, the eleventh century distinguished astronomer, Ibn Yūnus of Egypt (d. 1008), confirms that when he speaks of Khafīf in such high terms that in his mind he stands out as an astrolabe maker in the same way Galen stands out in medicine, and Ptolemy in demonstrative sciences.[4]

It is not therefore surprising that an astrolabe made by such a distinguished maker should be sought after still as late as

[3] In this context one should note that in all instances, where an apprentice relationship can be established, al-Nadīm uses the term *ghulām*, except in the last instance of the female astrolabist who is referred to as the *tilmīdha* of Biṭūlus, because the feminine **ghulāma* is not used in Arabic.

[4] «... It is possible that some one (distinguished person) could be found at a specific time and it would be difficult to find others like him for a long time, such as Ptolemy in the demonstrative sciences, Galen in medicine, and Khafīf ghulām 'Alī b. Īsā in the making of astrolabes and Ḥāmid al-Wāsiṭī», Ibn Yūnus, al-*Zīj al-Ḥākimī, op. cit.*, p. 55.

sixteenth-century Italy, hence the reason for the appearance of its drawing by Antonio da Sangallo the Younger. On the other hand, these drawings of what looked like a genuine astrolabe were very curious still.

First, Antonio the Younger did not know any Arabic to be able to copy what he must have had in front of him with such fidelity. Second, the type of astrolabe he was copying was generally of the style known from medieval Andalus (i.e. medieval Spain), while he signaled at the lower part of Figure 1 that the astrolabe was Egyptian (*Egyptizio*). The reason for the Andalusian connection is that the drawing, which we must assume was quite close to the original, had the two standard concentric circles usually found on the backs of Andalusian astrolabes made in the tenth or eleventh centuries, or even later, designating the zodiacal signs, marked for every degree, and the calendar months, marked for every day. It is easy to note, for example, that in this drawing the Vernal Equinox, 0° Aries, was clearly marked at March 15, as was the case in a good number of Andalusian astrolabes.

By examining the script on these two additional circles, one can easily detect that they were not of the same quality as the other script used for the signature, the degree scales at the rim (Figure 1), or for the names of the stars and the zodiacal signs on the rete (Figure 2). Even the designation of the shadow units, *al-ẓill al-mankūs* and *al-ẓill al-mabsūṭ*, clearly marked in the central square on the back (in the lower right-hand quadrant on the back, left side of Figure 1) were not in the same style as the two concentric circles, and looked more like the original *kūfī* script of the remaining inscriptions.

Trying to compare this drawing with the surviving works of Khafīf did not help very much. First, as far as we can tell, we have only one complete astrolabe attributed to Khafīf, and part of an astrolabe, a rete, now kept at the Oxford Museum of the History of Science under the numbers (57-84/155) and (57-84/156) respectively.[5] Second, the back of the unique surviving astrolabe

[5] I am grateful to my colleague, David King of Frankfort University, who first shared with me his notes on the Oxford Khafīf astrolabe and rete, before I had access to their photographs. My special thanks to Mr. Francis R. Maddison who later supplied me with the actual photographs, and drew my attention to the following bibliographical items: F. R. MADDISON, *A Supplement to a Catalogue of Scientific Instruments In the Collection of J. A. Billmeir, Esq., C.B.E. Exhibited by the Museum of the History of Science, Oxford*, Oxford & London, 1957, pp. 16-17, no. 155, & pl. XXIIIa, & p. 18, no. 156; F. MADDISON and A. TURNER, *Catalogue of an Exhibition, 'Science and Technology in Islam', held at the Science*

(Figure 3) was definitely modified by a later maker (?), probably an Armenian, and did not contain any of the 'Andalusian Circles' mentioned above. Third, even the shadow square of the surviving astrolabe is placed on the left-hand side, in the lower left-hand quadrant of the back, and marked with Armenian inscriptions only. This could only mean that the unique surviving Khafīf astrolabe, the only one with which we could compare Antonio's drawing, was in effect an earlier example of the works of Khafīf, since it did not seem to have the shadow square on its back. The rest of the engravings on the back of the surviving astrolabe, i.e. the degree scales, match very well with the style of writing in the drawing (compare Figures 1 and 4). Note, for example, the special shape of the *'ayn*, marking the seventieth degree on the upper rim of the left hand quadrant. Note also the use of *sīn*, marking the sixtieth degree, instead of *ṣād* (which one would have expected from an Andalusian astrolabe) in both the surviving Khafīf astrolabe of Oxford and on Antonio's drawing. Allowing for slight insignificant variations in the paleography of the drawing, as compared to the markings on the surviving astrolabe and as one would naturally expect from a drawing by one who did not read Arabic, nevertheless one can be certain that we are dealing with a drawing of yet another genuine Khafīf astrolabe, whose provenance was indeed the eastern provinces of Islam as the designation «*Egyptizio*» can be taken to mean.

The additional similarities between the drawing of the rete by Antonio the Younger and the two retes preserved at Oxford, one with the complete astrolabe and the second single one, further confirm the authenticity of the original astrolabe used by Antonio. Note specifically the peculiar kink, used to designate the star *kaff al-khaḍīb* (β Cas) just to the left of the central hole and above the bar in all three examples of the rete, Figures 2, 4, and 5. Also note the identical number and location of stars in all three retes. Furthermore, all three retes have the same type of star pointers, all straight like the old pen-tips. In all three retes, the star *qalb al-'aqrab* (α Sco) is designated by similar pointed ends of the

Museum London, April-August 1976, in association with the Festival of Islam, not published commercially, incomplete typescript, without illustrations, made available in a limited number of copies for private circulation, Paris, 1976, p. 98, no. 36 and p. 59, no. 37 (*rete*); and A. Brieux and F. Maddison, *Répertoire des facteurs d'astrolabes et de leurs oeuvres: Islam, plus Byzance, Géorgie et Inde hindoue*, Paris (forthcoming), *s.v.* Khafīf. A picture of the back of the Khafīf astrolabe was also published as Plate I in L. A. Mayer, *Islamic Astrolabists and Their Works*, Albert Kundig, Genève, 1956.

Capricorn circle rather than separate pointers. Although this feature is common to other astrolabes, it is the similarity of the pointers and their engravings that distinguish these three retes. Finally, in all three retes the name for the zodiacal sign Pisces is given as *al-samaka* instead of the more usual *al-ḥūt* that one finds on other astrolabes.

Another confirmation of the authenticity of Antonio's drawing lies in the shape of the throne (*kursī*) of the Oxford astrolabe and the one represented in the drawing. The peculiar two dots, with the pin of the hanger adding a third to form a triangular shape, with the outer three lobes encompassing them and the angular base attaching the throne to the mater, are all so peculiar that it is highly unlikely they would have been made by different astrolabists.

In light of all these remarkable similarities I became convinced that the astrolabe from which Antonio made his drawing was first a genuine astrolabe made by Khafīf *ghulām* 'Alī b. 'Īsā, the same astrolabist who made the Oxford astrolabe and rete. Second I now believe that the astrolabe which was drawn was indeed a better astrolabe than the one that has survived, in the sense that it had more features, namely the shadow square. Conversely, I also believe that the mere existence of Antonio's drawing, which will be described below, confirms that the Oxford astrolabe and the Oxford rete were both indeed made by Khafīf.

The Date of Khafīf's Astrolabe

In the previously cited chart we note that Khafīf was dated to approximately the mid-ninth century. This approximate date was based on the following evidence. There is no reason to doubt the apprenticeship affiliation of Khafīf to 'Alī b. 'Īsā, both marked on the surviving astrolabe and Antonio's drawing, and explicitly mentioned in the text of al-Nadīm. Althbough it is very hard to tell the difference in age between the master and the apprentice, one can still make some assumptions about their relative ages. We know from other sources that the master 'Alī 'b. 'Īsā was also called al-Ḥarrānī, and he was commissioned by al-Ma'mūn, together with Khālid al-Marwarūdhī and Sind Ibn 'Alī, to measure the one degree of the meridian in the desert of Sinjār.[6] Since al-Ma'mūn died in

[6] See, for example, Al-Bīrūnī, Abū al-Rayḥān, *al-Qānūn al-Mas'ūdī,* Dā'irat al-Ma'ārif

833 A.D., this can only mean that 'Alī must have already been a practicing scientist by at least that time if not before. This could also mean that he was about thirty years of age. His apprentice Khafīf could not be very much younger than he and was probably fifteen at that time. By 850 he was probably thirty-five years old himself and began to have his own students like the famous Bīṭūlus who is credited with more than one surviving astrolabe.[7] Actually the remarkable similarities between the works of this Bīṭūlus and those of Khafīf, especially in regard to the shape of the star pointers, the names of the stars and their number, the shape of the *kursī*, and the name of Pisces as *al-samaka*, confirm the textual tradition regarding this apprenticeship, which may go back to 'Alī b. 'Īsā and Ibn Khalaf al-Marwarūdhī themselves. Knowing that Khafīf's student was producing astrolabes during the first quarter of the tenth century, and that Khafīf himself was about thirty-five years old in 850, it would be quite unlikely that he lived long enough to witness the best production of his student some seventy seven years later, which would make him live well beyond one-hundred years.

Therefore, Khafīf must have lived sometime between 830 when his teacher 'Alī b. 'Īsā was a famous instrument maker and 927/28 when his own student was producing astrolabes. The most likely date for his own production must therefore be towards the mid-ninth century.[8] This can only mean that Khafīf's surviving astrolabe is the oldest one surviving that we know of,[9] and Antonio's drawing is that of an astrolabe which was made around the same time.

The Back of Khafīf's Astrolabe (figure 1, left)

We have referred above to the fact that the name of Khafīf was clearly inscribed on the original astrolabe along the rim of the upper

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al-Osmānīya, Hyderabad, 1955, vol. 2, p. 653. Suter, Heinrich, *Die Mathematiker und Astronomen der Araber und Ihre Werke*, Lepzig, 1900, p. 13.

[7] See A. J. TURNER, *Time Measuring Instruments, part 1, Astrolabes and Astrolabe Related Instruments*, The Time Museum, Rockford, 1985, p. 14, n. 28. One of those astrolabes, ascribed to Basṭūlus and dated 315 (927/28), is now in al-Sabah Collection in the Kuwait National Museum, see Marilyn Jenkins (ed.), *Islamic Art in the Kuwait National Museum*, Sotheby, 1983, p. 39.

[8] This is the date accepted by Mayer as well, *Islamic Astrolabists, op. cit.*, p. 54.

[9] This is also accepted by Ibrāhīm Shawkat, «al-Asṭurlāb: Ṭuruq wa-Asālīb Rasmihi wa-Ṣan'atihi», *Majallat al-Majma' al-'Ilmī al-'Irāqī*, vol. 19 (1970), pp. 3-94, 238-239, esp. p. 11, and Turner, *op. cit.*

right-hand quadrant. That in fact would have replaced the scale markers that one would have expected there, as in the surviving astrolabe. But with these markers, which were clearly inscribed on the original astrolabe along the rim of the upper left-hand quadrant, the possible utility of the astrolabe to measure elevations was not therefore compromised.

The shadow square towards the center, in the lower right-hand quadrant was obviously inscribed on the original astrolabe with the same script as the one used for the signature and thus may very well have been perfectly copied by Antonio. As the drawing attests, the vertical scale for this square was clearly marked in the original as belonging to the tangent scale (*al-ẓill al-mankūs*) and the horizontal one was marked for the cotangent scale (*al-ẓill al-mabsūṭ*), both measured in units of twelve digits.[10]

The two concentric calendar circles, usually inscribed on western Islamic astrolabes from Andalus, must have contained, as was noted above, a clearly inferior script, as it is reflected in the drawing as well. With the assumption that Antonio was copying exactly what he had in front of him, the only conclusion that could be drawn is that these circles were later additions to Khafīf's astrolabe, and must have originated in medieval Spain. This is not surprising in light of the fact that the surviving astrolabe also had a practically empty back until it was later filled by some Armenian maker or owner by what looks like an extended trigonometric grid, which may allow for a crude reading of the sine function.

The Mater (Figure 1 right-hand side)

We do not know whether Antonio had any plates hidden within the mater of the original astrolabe or whether the mater itself was engraved as a plate for latitude 30°, and maximum day length of 14 hours, as it is shown in the drawing. The latitude circles (*muqanṭarāt*) were apparently marked on the original plate for every six degrees, and are here correctly drawn by Antonio starting with the horizon arc which passes precisely through the equatorial points as it should. The unequal hours which were marked 1 to 12 on the

[10] For a definition and discussion of the various parts and units of an astrolabe and their traditional placement, see S. GIBBS with G. SALIBA, *Planispheric Astrolabes From the National Museum of American History*, Smithsonian Studies in History and Technology, No. 45, Smithsonian Institution Press, 1984, pp. 1-60.

original astrolabe were apparently engraved beneath the horizon, as was usually the case. The outer rim of the mater was obviously marked for every degree for 360°, and was engraved with a peculiar *kūfī* script which was the same script used throughout except for the calendar circles, as can be clearly seen from Antonio's drawing. Antonio attempeted to identify the markers just outside the rim by using «Arabic numerals», designating only the numbers 5, 10, up to 120. Here the ink is the same color as that of his notes.

The Italian inscriptions in Figure 1, as read by G. Scaglia, are the following:

Under the left-hand drawing: «*da questa banda sta lo alidada*» (The alidade is on this side).

In between the two circles, the lower inscription: «*strolabio egyptizio da ritto et da verso*» (Egyptian astrolabe's face and dorso sides).

Under the right-hand drawing: «*da questa banda si incapassa le tavole luna sopra all altra cioe tre tavole e di poi la ragna qui retro disegniate*» (The plates on this side are assembled one above the other, that is, three plates, including the rete draughted on the other side of this sheet).

On the alidade and underneath it: «*alidada; gli busi dello alidada colli quali sintraguarda sono tutti dal mezo in la come sta segniata*» (Alidade; the holes of the alidade {through} which one looks all appear from the center to the end, as indicated).

Next to screw and rivet: «*vite femina; asse a vite quale se cingie le tavole et la ragna et lo alidado*» («Female screw» (nut); screw with which the plates, rete, and alidade are connected).

The Rete (Figure 2)

The similarities between Antonio's drawing of the rete and the preserved ones are so remarkbale that they leave no doubt concerning the attribution of the drawing to an astrolabe made by Khafīf. The number and names of the stars on all three retes are identical. Only the single rete, kept at Oxford, has *al-dajāja* (Cyg), for *dhanab al-dajāja* (α Cyg) in the other two, and Antonio's drawing has *mankib* (β Peg) for *mankib al-faras*. The remaining stars indicated on the drawing are:

Southern stars, counterclockwise, and radial:

al-dabarān (α *Tau)*
rijl al-jawzā' (β *Ori)*
mankib al-jawzā' (α *Ori)*
al-yamānīya (α *CMa)*
al-shāmīya (α *CMi)*
qualb al-asad (α *Leo)*

Northern stars, on the east-west bar and underneath it:

kaff al-khaḍīb (β *Cas)*
ra's al-ghūl (β *Per)*
al-'ayyūq (α *Aur)*
al-rāmiḥ (α *Boo)*

Northern stars counterclockwise and radial:

al-fakka (α *Cbr)*
qalb al-'aqrab (α *Sco)*
ra's al-ḥawwā (α *Oph)*
al-wāqi' (α *Lyr)*
al-ṭāyir (α *Aql)*
dhanab al-dajāja (α *Cyg)*
mankib [al-faras] (β *Peg)*

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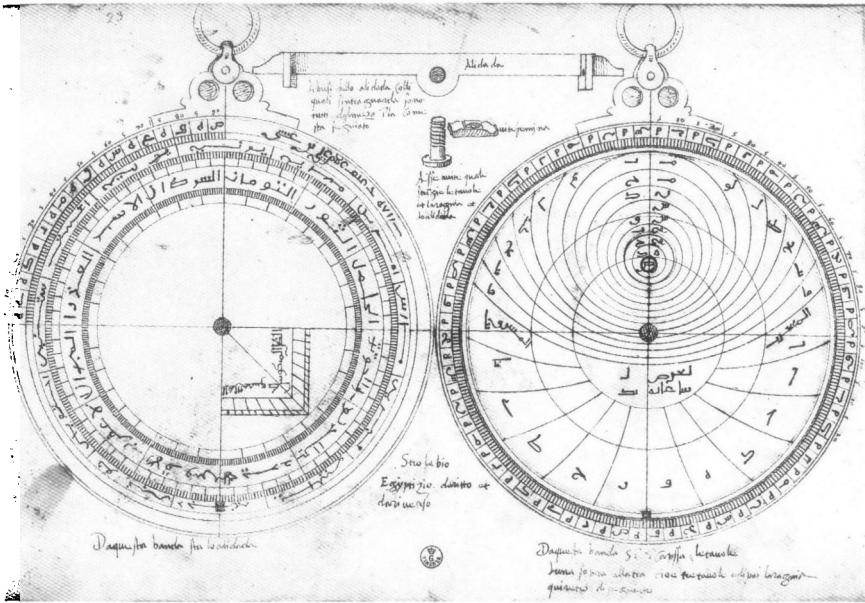
Figure 1. Antonio's drawing of the back and mater of Khafīf's astrolabe, now catalogued as U1454 A, *recto*.
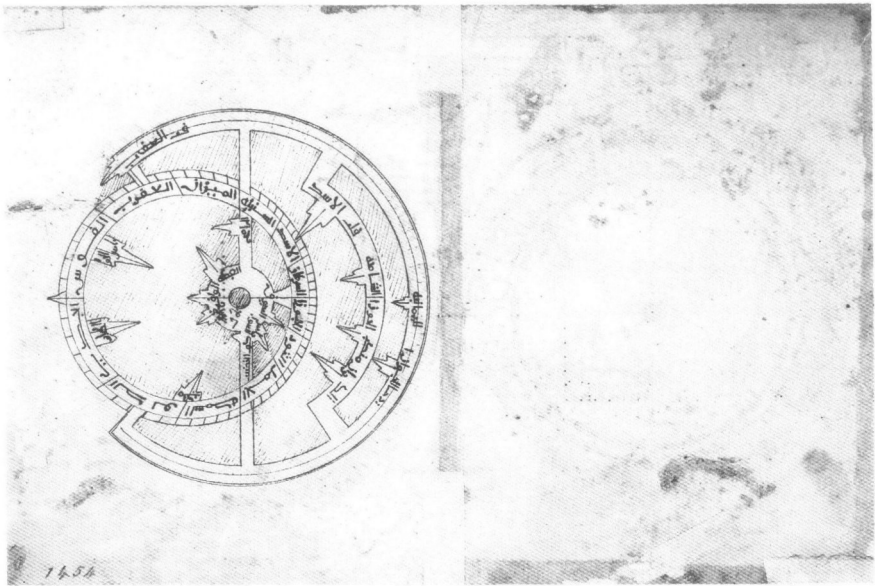
Figure 2. Independent drawing of the rete of Khafīf's astrolabe as executed by Antonio, now catalogued as U1454 A, *verso*.
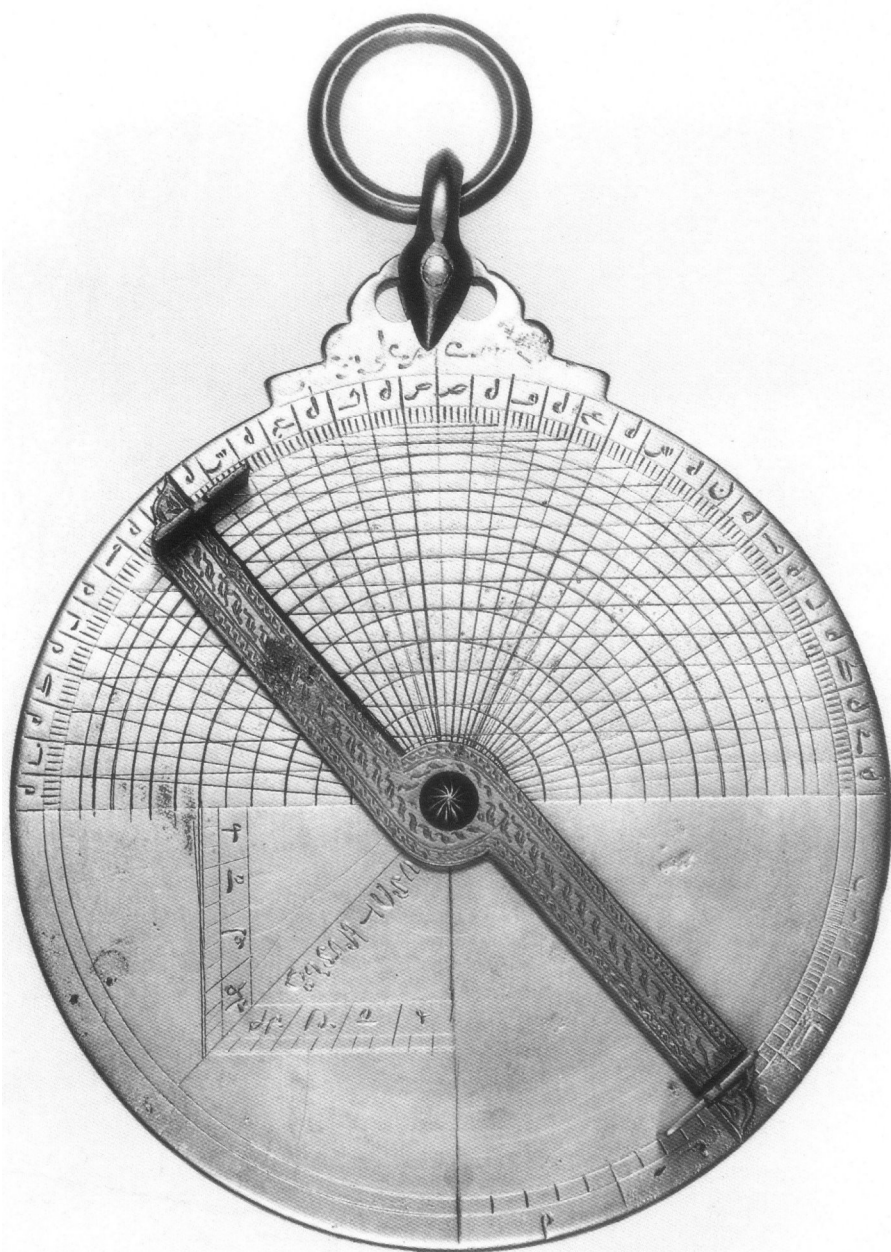
Figure 3. The back of Khafīf's astrolabe (courtesy of the Museum of the History of Science, Oxford, No: 57-84/155).

Figure 4. Khafīf's unsigned rete (courtesy of the Museum of the History of Science, Oxford, No: 57-84/156).
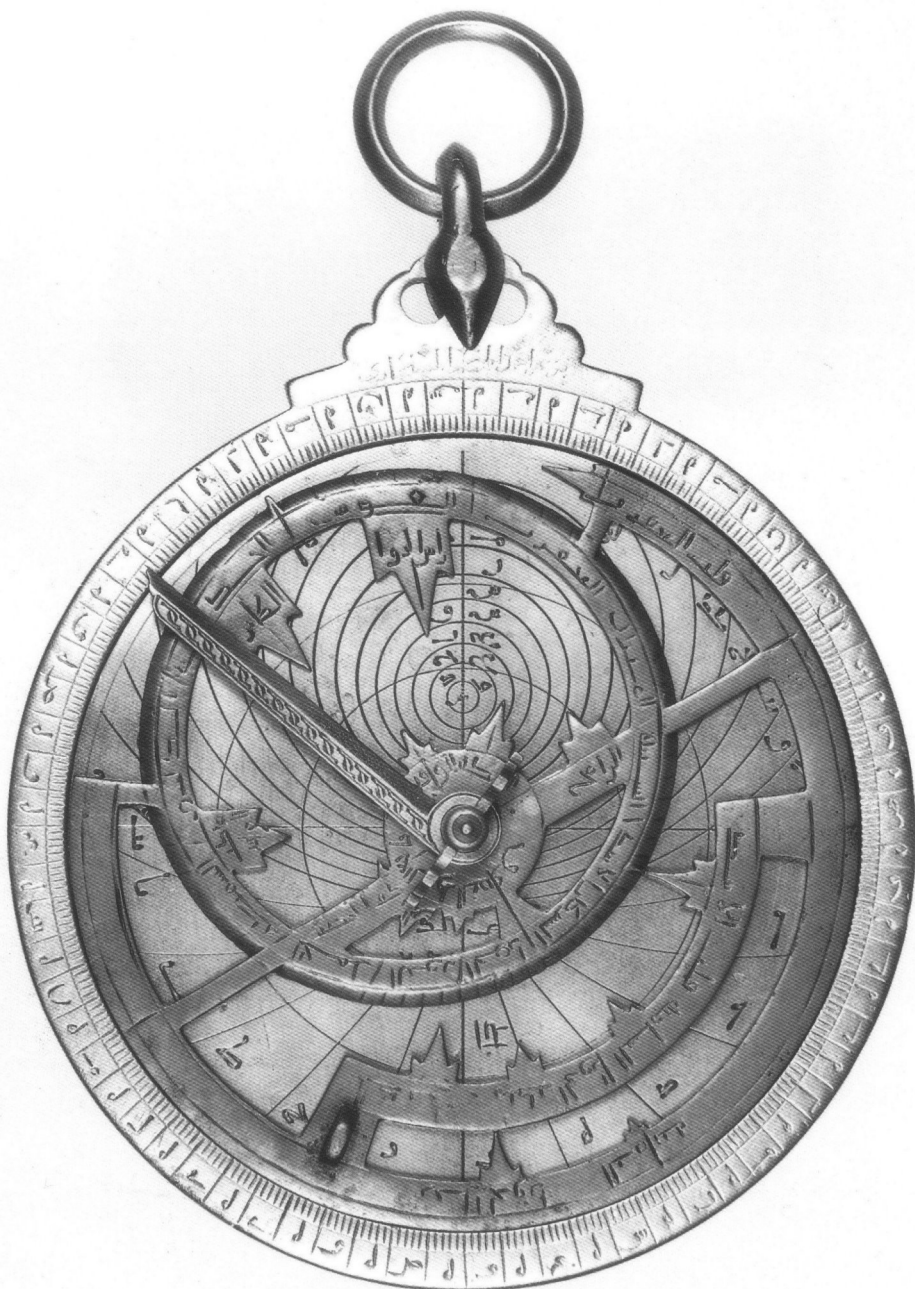
Figure 5. The Front of Khafīf's astrolabe, including the original rete (courtesy of the Museum of the History of Science, Oxford, No: 57-84/155).

SUMMARY

This article identifies a drawing executed by the Renaissance Florentine architect Antonio da Sangallo Giovane of an astrolabe that was made by the famous Baghdad astrolabist Khafīf the student of 'Alī b. 'Īsā (c. 850 A.D.). The only extant astrolabe of Khafīf that we know of is kept at the Museum of the History of Science, Oxford, a picture of which is published here as evidence of the identification. Because of the remarkable precision of Antonio's copy, and because of the similarity of Antonio's copy to another part of an unsigned astrolabe - the rete - also kept at Museum of the History of Science at Oxford, the present author was allowed to confirm that the unsigned part must have been made by the same astrolabist, Khafīf. The article concludes that the astrolabe from which the drawing was made must have been a later work of Khafīf, for it was obviously more complete than the extant one at Oxford, and was also added to in Andalusia before it reached Antonio.